Increment and Mortality in Cutover Stands of Ponderosa Pine as Based on Records of Permanent Sample Plots

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RM REPRINT

March, 1933

Increment and Mortality in Cutover Stands of Ponderosa Pine as Based on Records of Permanent Sample Plots

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During the period of 1909 to 1913 several large permanent sample plots were established in cutover stands of ponderosa pine in the Coconino and Tusayan National Forests. The plots have been periodically measured at intervals of 5 years and so far a record of increment and mortality covering a total of 15 to 20 years has become available. The results, based on this record, are briefly presented in this report.

The designations and areas of the plots, together with the time of establishment and length of record, are shown in Table 1. Plots S-3 and S-4, which were established in 1909, represent stands that were cut under the group-selection method. Those listed under the designation S-5 represent stands cut under three different methods. Since these latter plots are adjacent, the data obtained from them should be especially valuable from a comparative standpoint. With the exception of S 4, which is on the cinder areas east of Flagstaff, the plots were established immediately after the areas had been logged. The manner in which the plots differ with reference to distribution of trees and volume reserved is shown in Table 2.

The results based on the present record of the plots are shown in the following tables and figures. Figures 1 and 3[1] show the distribution of the trees on two plots, representing different types

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[1] Several of the graphs used in the original manuscript have been omitted.

of stand, at time of establishment and 15 to 20 years later. Table 3 shows the net volume per acre at the time the plots were established and at the end of different periods thereafter. These data are shown graphically in Figure 6b. The mean annual increment per acre and percentages of increment, based on the data in Table 3, are shown in Table 4. The periodic annual increment, i.e., the annual increment as based on the net volume per acre on hand at the beginning of each five-year period, is shown in Table 5. The relation between volume per acre and the rate of increment is shown in Figure 7a[2]. To what extent the increment of the stands is reduced by mortality is shown by the data in Tables 6 and 7. Table 8 shows the estimated time that must elapse before a volume of 6,000 feet board measure will again be available for cutting, and also the volume that each plot should have in 60 years from the time of the first cut.

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[2] It should be noted that these are the same values as plotted in Figure 6b, but instead of the absolute changes in volume, the slopes of the curves indicate the rate of change. The reason for this difference is that the vertical scale of the charts used here is logarithmic instead of arithmetic.

Discussion of Results

Because of the large size of the plots, it might be assumed that the data should be directly applicable to larger areas. But this assumption must be verified before any definite conclusions to that effect can be drawn. Certain deductions may, however, be made from the data as they stand.

Attention is first of all called to the graphs in Figures 1 and 3 depicting the changes in distribution of diameter classes. Plot S-5 I shows a decided improvement in distribution in that it now more nearly conforms to that desired in a forest managed for sustained yield under a selection system of cutting.[3] Building up of the diameter classes from 18 inches down is especially important. The fact that the distribution has not improved on Plot S-3 indicates a deficiency of poles and saplings at the time the plot was established. Restocking since 1918 has been excellent, but these young trees are still below the four-inch diameter class. The other plots, except S-4, also contain large numbers of seedlings and saplings below four inches d.b.h. As time goes on there should be a substantial increase in numbers throughout the diameter classes below about 18 inches. A trend in this direction is noticed in Figure 3.

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[3] Just what constitutes a normal distribution of diameter classes in a selection forest has not been definitely determined, but obviously the number of trees in the smaller diameters should be considerably greater than in the larger diameters. It might be assumed that the number of trees in the different diameter classes should be inversely proportional to the squares of the diameters, giving a distribution curve of hyperbolic form. But although this may be the ideal distribution, it is probably never attained.

Examining next the graphs in Figure 7b, which shows the rate of change in volume, it will be observed that the character of change is similar for all of the plots. That is, the rate of volume increase begins to fall off 10 years after cutting. If this decline continues, as the present data indicate, it is evident that allowance for this must be made in predicting the volume expected to become available for the next cut. In the absence of a long time record, the best that can be done is to estimate the future volume on the basis of data already accumulated. In extending the estimates beyond the present period, one should probably use as a basis the mean of the current periodic increment, rather than the mean of the total period. Results obtained by both methods are shown in Table 5.

Although there is no assurance that the increment data from the present plots are applicable to other stands, it would seem that by applying the increment per cent values to stands cut under methods similar to those represented by the plots, a fairly good estimate of the future yield would be obtained. The increment per acre would, on the other hand, only apply where the volume per acre reserved happened to be the same as on the sample plots. However, in attempting to predict the increment for an entire working circle, it would seem better to use the method of applying the growth of average trees to a stand table, as has been advocated in a previous article. [4]

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[4] Krauch, Hermann. The Determination of Increment in Cutover Stands of Western Yellow Pine in the Southwest. Journ. Forestry 28: 978-986.

Perhaps the most important fact brought out by the data obtained from the present plots is that a relatively large volume must be reserved if a second cut is to be made within a reasonably short time after the first cut. Where too small a volume is reserved, as on the Scattered Seed Tree Plot, it will take from 100 to 150 years before a volume large enough to justify cutting will again be available. In that event the large trees that are reserved for seed will probably all have died and therefore be a total loss. On the other hand, when too large a volume is left, it may, because of the necessity of leaving a large number of unthrifty or defective trees, give a relatively low return on the wood capital. This is shown by the results obtained on the Shelterwood Plot (S-5 III).

In order that an economic second cut may be made in 60 years following the first cut, it is estimated that an average of at least 2,500 board feet per acre, in trees 12 inches breast height and over, should be reserved. It would be better if volumes up to 4,000 board feet per acre were reserved, but this can not generally be done without leaving a large number of unthrifty trees, which, as has been shown, is not justified.

Table 1. Character of the Plots

Plot designation	Area of plot	Year established	Year of last measurement	National Forest	Method of cutting
	Acres				
S-3	456	1909	1929	Tusayan	Group selection.
S-4	304	1909	1929	Coconino	Group selection.
S-5 I	139	1913	1928	Coconino	Group selection.
S-5 II	152	1913	1928	Coconino	Scattered seed trees.
S-5 III	112	1913	1928	Coconino	Shelterwood.

Table 2. Number of trees, basal area and volume per acre by diameter classes on 5 plots at the time plots were established.

Diameter classes	S-3		S-4		S-5 I		S-5 II		S-5 III	
	Number of trees									
Inches	No.	%	No.	%	No.	%	No.	%	No.	%
4 - 11	6.3	35.0	5.9	38.6	10.3	46.0	4.5	53.6	10.1	42.4
12 - 20	7.7	42.8	6.8	44.4	9.0	40.2	1.7	20.2	9.1	38.2
21 & over	4.0	22.2	2.6	17.0	3.1	13.8	2.2	26.2	4.6	19.4
Total	18.0	100.0	15.3	100.0	22.4	100.0	8.4	100.0	23.8	100.0
	Basal area									
	Sq.ft.	%	Sq.ft.	%	Sq.ft.	%	Sq.ft.	%	Sq.ft.	%
4 - 11	2.6	9.6	2.1	10.2	3.5	13.5	1.4	11.4	3.6	10.9
12 - 20	11.0	40.6	9.4	45.6	11.9	45.8	2.5	20.3	12.2	37.1
21 & over	13.5	49.8	9.1	44.2	10.6	40.7	8.4	68.3	17.1	52.0
Total	27.1	100.0	20.6	100.0	26.0	100.0	12.3	100.0	32.9	100.0
	Cubic volume									
	Cu.ft.	%	Cu.ft.	%	Cu.ft.	%	Cu.ft.	%	Cu.ft.	%
4 - 11	41	5.6	26	5.0	46	7.4	15	4.1	52	5.6
12 - 20	255	34.6	208	40.3	240	38.5	52	14.3	264	28.3
21 & over	441	59.8	282	54.7	337	54.1	297	81.6	618	66.1
Total	737	100.0	516	100.0	623	100.0	364	100.0	934	100.0
	Volume, board measure									
	Bd.ft.	%	Bd.ft.	%	Bd.ft.	%	Bd.ft.	%	Bd.ft.	%
12 - 20	1077	30.6	833	35.8	968	34.0	218	11.6	1044	23.1
21 & over	2443	69.4	1495	64.2	1878	66.0	1655	88.4	3466	76.9
Total	3520	100.0	2328	100.0	2846	100.0	1873	100.0	4510	100.0

Table 3. Net volume per acre at different periods after cutting

Plot	Volume per acre after cutting									
	Cubic measure					Board measure				
	Years after cutting					Years after cutting				
	0	5	10	15	20	0	5	10	15	20
	Cu.ft	Cu.ft	Cu.ft	Cu.ft	Cu.ft	Ft.bm	Ft.bm	Ft.bm	Ft.bm	Ft.bm
S-3	737	807	904	978	1038	3520	3942	4518	4971	5339
S-4	516	568	645	707	768	2328	2603	3028	3362	3665
S-5 I	623	677	773	857		2846	3133	3617	4031	
S-5 II	364	384	428	460		1873	1956	2185	2325	
S-5 III	934	1007	1119	1195		4510	4918	5509	5899	

Table 4. Mean annual net increment, as based on different periods after cutting.

Plot	Increment per acre							
	Cubic measure				Board measure			
	Years after cutting				Years after cutting			
	5	10	15	20	5	10	15	20
	Cu.ft.	Cu.ft.	Cu.ft.	Cu.ft.	Ft.bm.	Ft.bm.	Ft.bm.	Ft.bm.
S-3	14.0	16.7	16.1	15.1	84	100	97	91
S-4	10.4	12.9	12.6	12.6	55	70	69	67
S-5 I	10.8	15.0	15.6		57	77	79	
S-5 II	4.0	6.4	6.4		17	31	30	
S-5 III	14.6	18.5	17.4		81	100	93	

Plot	Increment per cent							
	Cubic measure				Board measure			
	Years after cutting				Years after cutting			
	5	10	15	20	5	10	15	20
	%	%	%	%	%	%	%	%
S-3	1.90	2.27	2.18	2.04	2.39	2.84	2.76	2.59
S-4	2.01	2.50	2.46	2.44	2.36	3.00	2.96	2.88
S-5 I	1.73	2.41	2.51		2.00	2.71	2.77	
S-5 II	1.10	1.76	1.76		.91	1.66	1.60	
S-5 III	1.56	1.98	1.86		1.80	2.22	2.06	

Table 5. Periodic annual net increment

Plot	Increment per acre							
	Cubic measure				Board measure			
	Period°				Period°			
	1	2	3	4	1	2	3	4
	Cu.ft.	Cu.ft.	Cu.ft.	Cu.ft.	Ft.bm.	Ft.bm.	Ft.bm.	Ft.bm.
S-3	14.0	19.4	14.8	12.0	84	115	90	74
S-4	10.4	15.4	12.4	12.2	55	85	67	61
S-5 I	10.8	19.2	16.8		57	97	83	
S-5 II	4.0	8.8	6.4		17	46	28	
S-5 III	14.6	22.4	15.2		81	118	78	

Plot	Increment per cent							
	Cubic measure				Board measure			
	Period°				Period°			
	1	2	3	4	1	2	3	4
	%	%	%	%	%	%	%	%
S-3	1.90	2.40	1.64	1.23	2.39	2.92	2.01	1.49
S-4	2.01	2.71	1.92	1.73	2.36	3.27	2.21	1.81
S-5 I	1.73	2.84	2.17		2.00	3.10	2.29	
S-5 II	1.10	2.29	1.50		.91	2.35	1.28	
S-5 III	1.56	2.22	1.36		1.80	2.40	1.42	

°Successive periods of five years each.

Table 6. Mean annual mortality, based on different periods after cutting

Plot	Annual loss per acre							
	Cubic measure				Board measure			
	Years after cutting				Years after cutting			
	5	10	15	20	5	10	15	20
	Cu.ft.	Cu.ft.	Cu.ft.	Cu.ft.	Ft.bm.	Ft.bm.	Ft.bm.	Ft.bm.
S-3	2.4	3.2	3.7	4.1	11	15	18	20
S-4	1.2	1.6	1.5	1.7	6	7	7	8
S-5 I	5.2	4.4	3.7		26	22	18	
S-5 II	6.0	4.3	4.0		32	24	22	
S-5 III	5.4	5.1	6.3		27	26	29	

Plot	Annual loss per cent							
	Cubic measure				Board measure			
	Years after cutting				Years after cutting			
	5	10	15	20	5	10	15	20
	%	%	%	%	%	%	%	%
S-3	.33	.43	.50	.56	.32	.43	.51	.57
S-4	.23	.31	.29	.33	.26	.30	.30	.34
S-5 I	.83	.70	.59		.91	.77	.63	
S-5 II	1.65	1.18	1.10		1.70	1.28	1.17	
S-5 III	.58	.55	.68		.60	.58	.64	

Table 7. Periodic annual mortality

Plot	Loss in volume per acre							
	Cubic measure				Board measure			
	Period°				Period°			
	1	2	3	4	1	2	3	4
	Cu.ft	Cu.ft	Cu.ft	Cu.ft	Ft.bm	Ft.bm	Ft.bm	Ft.bm
S-3	2.4	4.0	4.8	5.2	11	19	24	26
S-4	1.2	2.0	1.4	2.2	6	9	7	11
S-5 I	5.2	3.6	2.2		26	17	10	
S-5 II	6.0	2.6	3.4		32	16	17	
S-5 III	5.4	4.8	8.8		27	25	36	

Plot	Loss in per cent of volume							
	Cubic measure				Board measure			
	Period°				Period°			
	1	2	3	4	1	2	3	4
	%	%	%	%	%	%	%	%
S-3	.33	.50	.53	.53	.32	.48	.53	.52
S-4	.23	.35	.22	.36	.26	.34	.23	.33
S-5 I	.83	.53	.29		.91	.54	.28	
S-5 II	1.65	.68	.79		1.70	.82	.78	
S-5 III	.58	.48	.79		.60	.51	.65	

°Successive periods of five years each.

Table 8. Estimate of volume per acre available in 60 years after cutting and number of years required to produce 6,000 board feet per acre

Plot	Volume left per acre	1 Present vol. per acre	2 Current ann. increment per acre (a)	3 Mean ann. increment per acre (b)	4 Vol. per A. in 60 yrs. (a)	5 Vol. per A. in 60 yrs. (b)	6 Time required to raise volume to 6,000 bd. ft. per A.
	Ft. b.m.	Ft. b.m.	Ft. b.m.	Ft. b.m.	Ft. bm	Ft. bm	Years
S-3	3520	5339	74	91	8299	8980	29
S-4	2328	3665	61	67	6105	6348	58
S-5 I	2846	4031	83	79	7766	7586	39
S-5 II	1873	2325	28	30	3585	3673	146
S-5 III	4510	5899	78	93	9409	10090	16

1 Volume 20 years after cutting for Plots S-3 and S-4; 15 years after cutting for S-5 plots.

2 Based on mean of last 5-year period.

3 Mean of 20 year period for Plots S-3 and S-4; mean of 15-year period for S-5 plots.

4 Current annual increment times years to go added to present volume.

5 Mean annual increment times 60 (years) added to volume left per acre.

6 Years already elapsed plus years to go as based on current rate of increment.

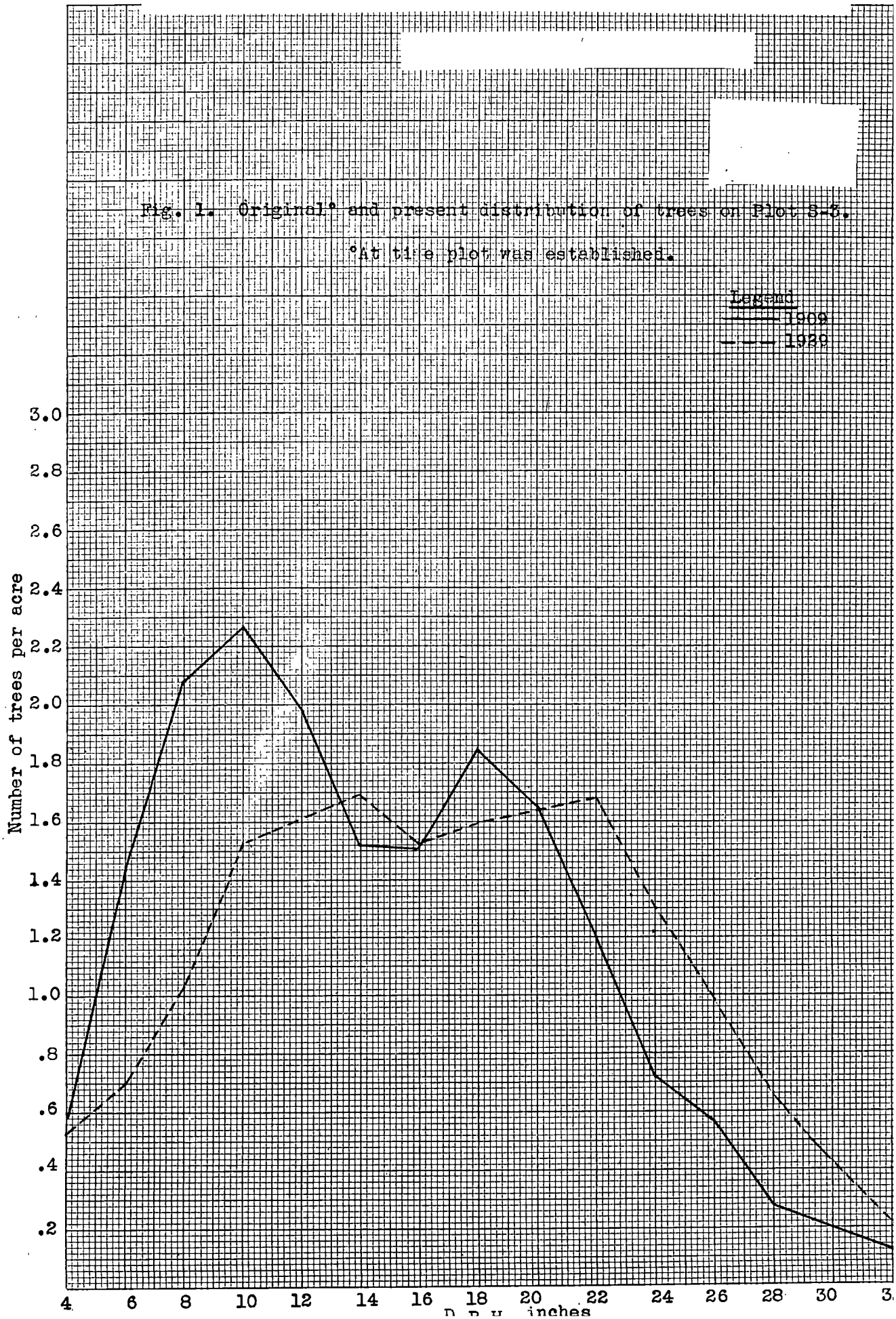


Fig. 1. Original° and present distribution of trees on Plot S-3.

°At the plot was established.

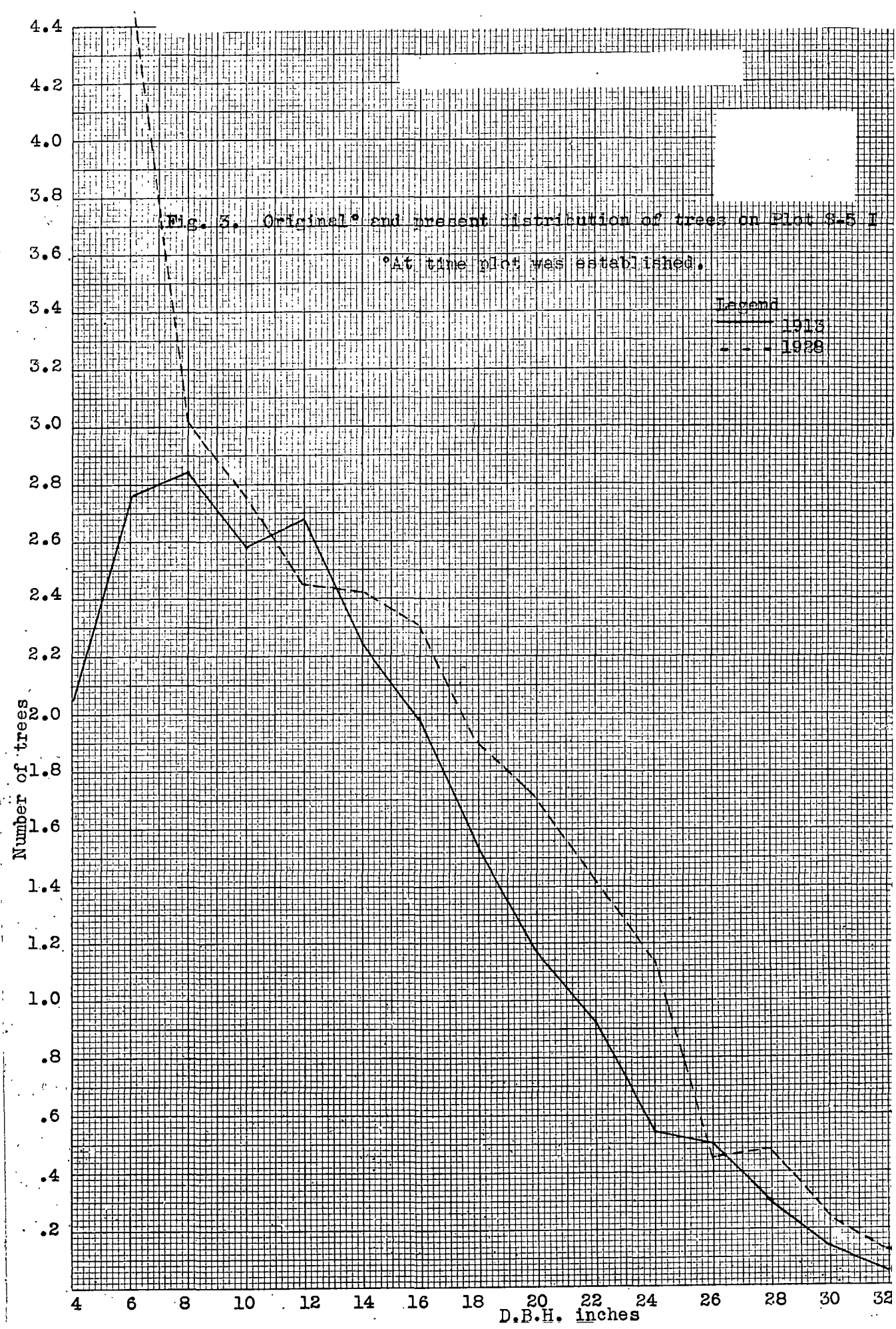


Fig. 3. Original* and present distribution of trees on Plot S-5 I

*At time plot was established.

Fig. 6 B. Relation between volume and net increment per acre.
Ft. b. m.

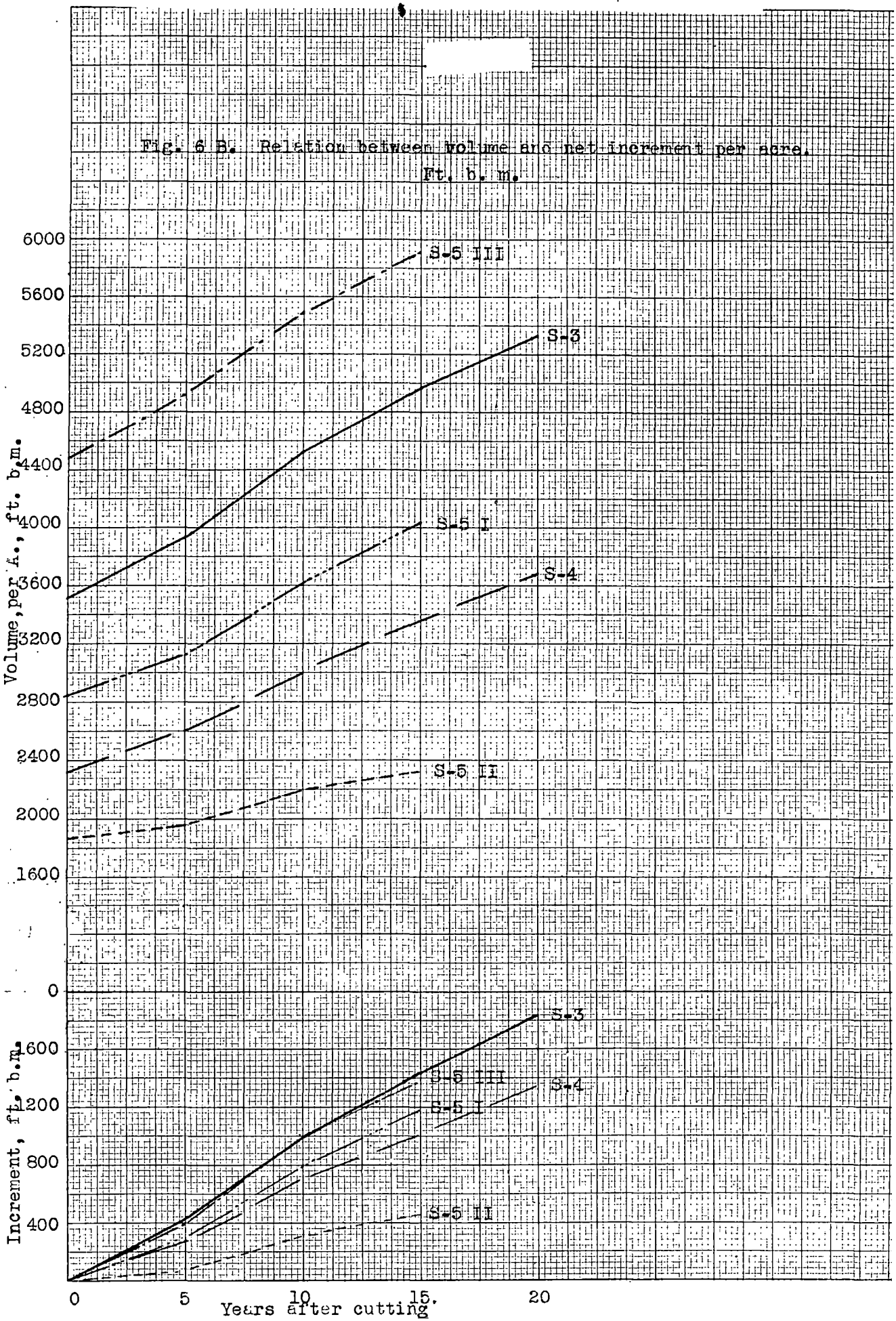
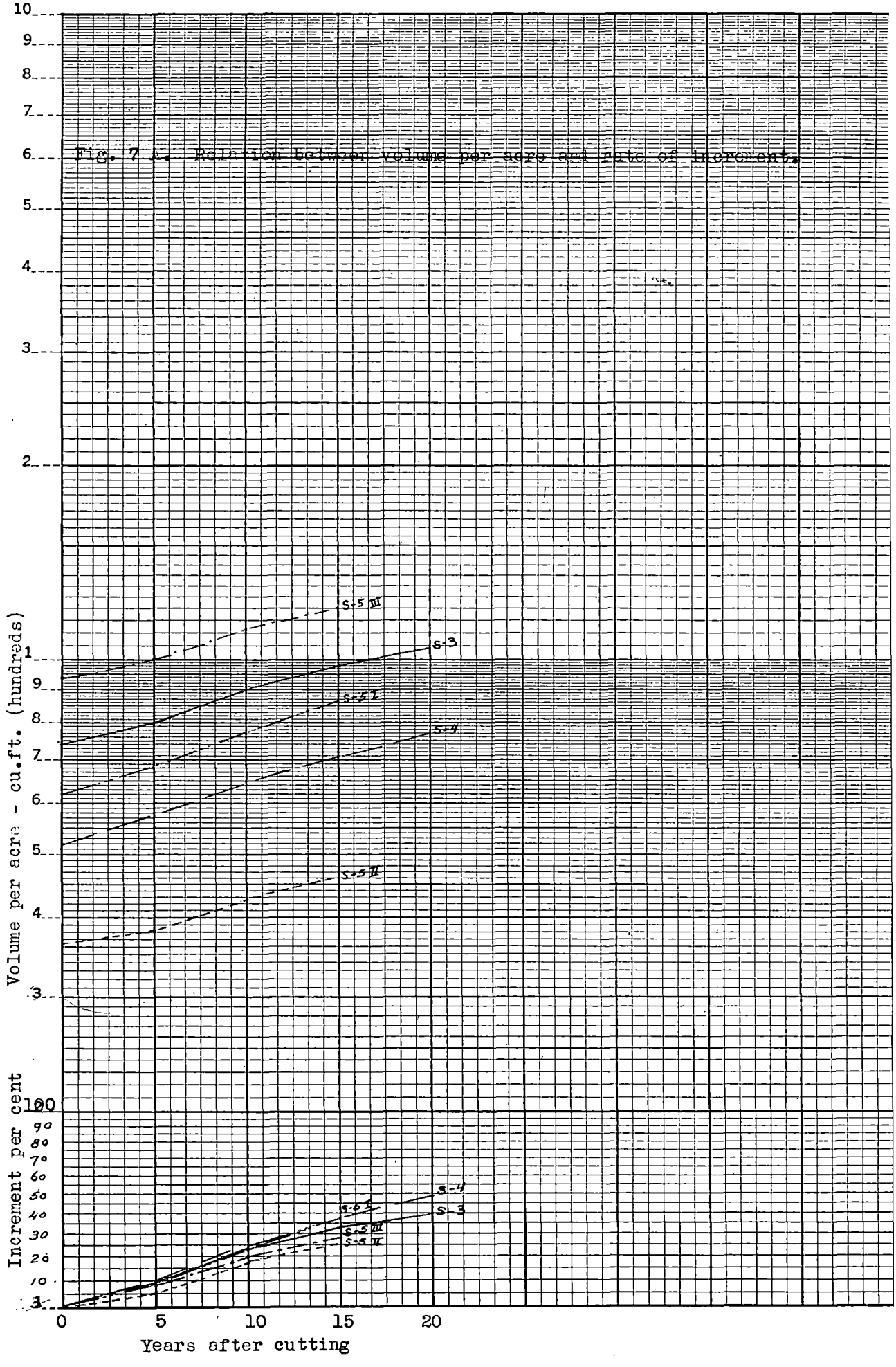


Fig. 7 a. Relation between volume per acre and rate of increment.



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